Flow behavior of particle suspensions in dry granular media scenarios

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Recent works on the flow of dry granular materials have deeply explored and improved the characterization of the flow of particles W through the aperture for spherical particles as a function of both relevant radii: aperture and particles [1, 2]

$$\begin{aligned} W &= \frac{2}{m}\int_0^D \sigma\phi(x)\boldsymbol{V}(x)dx \\ &= \frac{4}{\pi d^2}\beta\left(\frac{\upsilon+2}{2\upsilon},\frac{1}{2}\right)\sqrt{g}\,\phi_\infty\left[1-\frac{\alpha_1}{e^{R/\alpha_2}}\right]R^{3/2}, \end{aligned} \quad (1)$$

where m is the mass of particles, R is the radius of the particles, σ is the surface density, $\phi(x)$ is the volume fraction, $\boldsymbol{V}(x)$ is the velocity vector, g is the gravity acceleration, d is the hopper diameter, ϕ_∞ is the asymptotic value of the volume fraction, α_1, α_2 and υ are fitting parameters. This equation was found to be valid for two different orders of magnitude, including a region where clogging occurs, for a given set of fitting parameters [2].

Efforts to address the same problem in wet scenarios have been recently performed [3, 4] and they suggest that the Beverloo equation is also valid in an order of magnitude, implying that the fitting parameters in Beverloo equation are able to capture a much wider phenomenology than the one expected for the flow of dry granular materials.

The aim of the present work has been to experimentally study the flow of granular materials through hoppers in a range of different wet scenarios, by varying the setup angle, viscosity of the interstitial fluid and the ratio $r = 2R/d$. Our current experimental setup consists of a quasi-2D and transparent and sealed silo filled with 2 mm diameter beads of stainless steel and a mixture of 99.5% glycerin and pure water. The silo is portable enough such that we are able to keep it fixed in different angles, regarding the normal to the surface, using a mechanical scissor platform. The particles are left to fall under gravity and we record the process with a high resolution camera. Keeping the hopper size fixed, we have observed the linear behavior of the number of particles crossing the hopper regarding the time for different angles (see Fig. 1). The results presented here cannot be only described by using Beverloo equation.

In brief, we expect to further explore the flow behavior when changing variables such as viscosity, diameter ratio r and explore a wider range of angles and its limiting angle as a function of viscosity. To achieve those proposed goals, we are improving our experimental setup to easily adjust the mentioned variables and then record new videos and process the data.

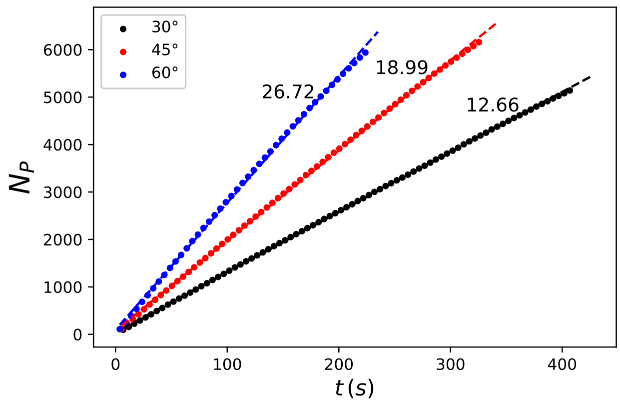

Fig. 1. Number of particles crossing the hopper as a function of time in seconds for different angles. The values shown are the slope of the plotted regressions. The data shown was halted from original data to consider only the steady-state regime.

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[4] A. M. Cervantes-Álvarez, S. Hidalgo-Caballero, F. Pacheco-Vázquez, The simultaneous discharge of liquid and grains from a silo, arXiv:1801.05747.